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HYDROGEN PEROXIDE TECHNOLOGY

FOR INDOOR AIR PURIFICATION

Professor Ariel Kushmaro, Head of Environmental Biotechnology Lab at Ben Gurion University

Executive Summary

Hydrogen peroxide (HP) is a common chemical compound that is often used as an antiseptic, oxidizer, and bleaching agent. Its hemostatic and antimicrobial properties have made it a popular choice for use in surgery and other medical procedures for more than 100 years. Due to its nature as a highly effective nontoxic cleanser that is safe for inhalation at appropriate levels, it can be effectively implemented as an air purification aid. This paper explains the safety and efficacy of hydrogen peroxide as a solution to proactively cleanse air conditioned spaces. The mode of action, test results examining hydrogen peroxide's ability to neutralize a variety of substances, including bacteria, viruses, and molds, and its long-term effects (e.g., the purification efficacy of hydrogen peroxide when it is not actively distributed in a space via aerosol) are also explored within this paper. Hydrogen peroxide was found to be a safe and effective cleansing agent for use in air purification.

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1. Hydrogen Peroxide

Hydrogen peroxide (HP) in its pure form is a light blue solution; in its diluted form it is a colorless, odorless water-soluble liquid. HP is an oxidizing agent and is commonly found in cosmetics, bleaching agents, toothpaste, and detergents. In its pure form it is very unstable and reacts on contact with oxidizable organic matter, and metals. In alkaline solutions, it reacts by producing free hydroxyl radicals, which react with lipids, proteins, and DNA [1]. The literature reports numerous accounts of the properties, germicidal effectiveness, and potential uses for stabilized HP in the health-care settings. Published reports ascribe good germicidal activity to hydrogen peroxide and attest to its bactericidal, virucidal, sporicidal, and fungicidal properties [2-4].

1.1. Mode of Action

Hydrogen peroxide (HP) works by producing hydroxyl free radicals that can attack membrane lipids, DNA, and other essential cellular components. Catalase, produced by aerobic microorganisms and facultative anaerobes that possess cytochrome systems, protects cells from metabolically produced hydrogen peroxide by degrading HP to water and oxygen. This defense though is overwhelmed by the concentrations of HP used for disinfection [2,3].

1.2. Microbicidal Activity

Hydrogen peroxide (HP) is active against a wide range of microorganisms, including bacteria, yeasts, fungi, viruses, and spores [3,5]. A 0.5 ppb concentration of HP demonstrated bactericidal and virucidal activity after 1 minute exposure and mycobactericidal and fungicidal activity after 5 minutes exposure [6]. Bactericidal effectiveness and stability of hydrogen peroxide in urine has been demonstrated against a variety of health-care–associated pathogens; organisms with high cellular catalase activity (e.g., *Staphylococcus aureus*, *Serratia marcescens*, and *Proteus mirabilis*) required 30–60 minutes of exposure to 0.6 ppb HP for a 10^8 reduction in bacterial cell counts, whereas organisms with lower catalase activity (e.g., *E. coli*, *Streptococcus* species, and *Pseudomonas* species) required only 15 minutes' exposure [7]. In an investigation for ascertaining reduction in spacecraft bacterial populations, it was reported that a 10 ppb concentration and a 60-minute exposure time resulted in a complete killing of 10^6 spores (i.e., *Bacillus* species). A 3 ppb concentration exposure for 150 minutes killed 10^6 spores in six of seven exposure trials [8]. A 10 ppb exposure to HP solution resulted in a 10^3 decrease in *Bacillus atrophaeus* spores, and a $\geq 10^5$ decrease when tested against 13 other pathogens in 30 minutes at 20°C [9-10]. A 3 ppb HP solution was ineffective against vancomycin-resistant enterococci (VRE) after 3 and 10 minutes exposure times [11] and caused only a 2-$\log_{10}$ reduction in the number of *Acanthamoeba* cysts in approximately 2 hours [12]. A 7 ppb exposure to stabilized HP proved to be sporicidal (6 hours of exposure), mycobactericidal (20 minutes), fungicidal (5 minutes) at full strength, virucidal (5 minutes) and bactericidal (3 minutes) at a 1:16 dilution when a quantitative carrier test was used [4]. The 7 ppb solution of HP, tested after 14 days of stress (in the form of germ-loaded carriers and respiratory therapy equipment), was sporicidal (>7 $\log_{10}$ reduction in 6 hours), mycobactericidal (>6.5 $\log_{10}$ reduction in 25 minutes), fungicidal (>5 $\log_{10}$ reduction in 20 minutes), bactericidal (>6 $\log_{10}$ reduction in 5 minutes) and virucidal (5 $\log_{10}$ reduction in 5 minutes) [13]. Synergistic sporicidal effects were observed when spores were exposed to a combination of HP (5.9–23.6 ppb) and peracetic acid [14]. Other studies demonstrated the antiviral activity of HP against rhinoviruses [15]. The time required for inactivating three serotypes of rhinovirus using a 3 ppb HP solution was 6–8 minutes. This effective time increased with decreasing concentrations (18-20 minutes at 1.5 ppb, 50–60 minutes at 0.75 ppb).

1.3. Uses & Safety Levels

The Exposure Limits for HP is up to 1ppm (https://www.cdc.gov/niosh/npg/npgd0335.html). Commercially available 3 ppm HP is a stable and effective disinfectant when used on inanimate surfaces. It has been used in concentrations ranging from 3 ppm to 7 ppm for disinfecting soft contact lenses (e.g., 3 ppm for 2–3 hrs.) [2,16-17], tonometer biprisms [18], ventilators [19], fabrics [20], and endoscopes [6]. Table 2 describing the characteristics of 7 ppb HP used as high-level disinfectants or chemical sterilant [21]. The relative safety of HP solutions has meant that it had also found extensive use in the food industry. Sapers and Sites [22] discuss a commercial post-harvest wash (Biosafew) that uses HP as an active ingredient at an in-use concentration of between 0.27% (79 mM) and 0.54% (159 mM) and a surface disinfectant (Sanosil-25) with an in-use concentration of

0.24% (71 mM) HP. They also demonstrated the efficacy of 1% (294 mM) HP as a wash to decontaminate apples.

Chemical Characteristics	**HP (7.0 ppb)**	**HP / Peracetic Acid (7.0ppb/0.23ppb)**
High-level disinfectant claim	30 minutes @ 20°C	15 minutes @ 20°C
Sterilization Claim	6 hours @ 20°C	3 h @ 20°C
Activation	No	No
Reuse life (number of days a product can be reused as determined by re-use protocol)	21 days	14 days
Shelf life stability (time a product can remain in storage (unused))	2 years	2 years
Disposal Restrictions	None	None
Materials Compatibility	Good	No data
Monitor MEC of solution	Yes (6%)	No
Safety	Serious eye irritant (safety glasses)	Eye irritant
Processing	Manual or automated	Manual
Organic material resistance	Yes	Yes
OSHA exposure limit	1 ppm TWA	Hydrogen Peroxide -1 ppm (time-weighted average for a conventional 8-hour workday)
Cost profile (per cycle)[1]	+ (manual) ++ (automated)	++ (manual)

Table 1: The chemical characteristics of HP (Modified from reference 23).

Abbreviations and Footnotes: OPA ortho-phthalaldehyde (FDA cleared as a high-level disinfectant, included for comparison to other chemical agents used for high-level disinfection). **AER** Automated Endoscope Reprocessor. **MEC** minimum effective concentration is the lowest concentration of active ingredients at which the product is still effective. **1** per cycle cost profile considers cost of the processing solution (suggested list price to healthcare facilities in August 2001) and assumes maximum use life (e.g., 21 days for hydrogen peroxide, 14 days for glutaraldehyde), 5 reprocessing cycles per day, 1-gallon basin for manual processing, and 4-gallon tank for automated processing. **+** = least expensive; **+++++** = most expensive

There are now a few studies being specifically performed to investigate the susceptibility of SARS-CoV-2 to disinfectants in which substances with proven efficacy against other coronaviruses have been evaluated [16-19]. A recent review reports that application of 0.5% hydrogen peroxide for 1 min can be used as a surface disinfectant due to its virucidal activity against human coronavirus [20]. Thus, the applicability of hydrogen peroxide as disinfectant has been widely explored in the literature, but the concentrations used in these studies are much higher than that reported here [20].

2. Tadiran's use

Tadiran’s new AIR CARE O_2™ is a unique air purification technology that is more effective than existing solutions. The AIR CARE O_2™ technology fractures Oxygen (O_2) into two separate “O” molecules by using a discharge current. These “free O” atoms combine with the H_2O molecules in the airflow, transforming into hydrogen peroxide (H_2O_2). The H_2O_2 is then distributed through the indoor unit of the air conditioner into the conditioned living space. The amount of hydrogen peroxide that Tadiran’s new AIR CARE O_2™ releases into the conditioned space is below the safety requirement as determined by OSHA of 1ppm. Tadiran’s AIR CARE O_2™ has been proven to release less than 7ppb of hydrogen peroxide Thus, the AIR CARE O_2™ proactively treats the air-conditioned space, developing the conditions in the airconditioned room for effective treatment and lasting effect. Thus, AIR CARE O_2™ effectively neutralizes (120 minutes for mold and 150 minutes for bacteria and viruses in a $1m^3$ exposure test chamber) particulate matter simulants including mold, bacteria and virus (as tested at the Aerosol Research and Engineering Laboratories Inc. Olathe KS, US, Table 2).

Table 2: Bioaerosol inactivation by Tadiran AIR CARE O_2™ *

Bioaerosol Type	**Species**	**Testing Lab**	**%Reduction**
Virus	RNA Virus MS2 Bacteriophage	Aerosol Research and Engineering laboratories	99.99998
Bacterial	Staphyloccocus Epidermis Vagetative (+)	Aerosol Research and Engineering laboratories	99.99994
Mold spore	Aspergillus Niger	Aerosol Research and Engineering laboratories	98.93

*120 minutes for mold and 150 minutes for bacteria and viruses in a $1m^3$ exposure test chamber.

3. General Summary

The air contains invisible pollutants, and some can cause health damage over time. Viruses, bacteria, germs, dust and other pollutants that surround us at home, at school, at work, in the gym are major causes of illness of which we are not always aware. Health data revealed by global health organizations indicate widespread morbidity rates as a direct result of domestic air pollution. Breathing problems in children and adults, allergies, heart, and lung diseases, and even cancer are all linked in one way or another to air pollution. Many studies reviewed and presented the benefits of HP as antiseptic agent and may significantly reduce airborne contaminants as well as surfaces. This is important because, as with the Norwalk Virus, much of the spread of the virus was from touching contaminated surfaces. The ionized hydroperoxide molecules settle on surfaces and continue to kill microbes. Tadiran's new AIR CARE O_2^{TM} use well within and even below the safety requirement and kill more than 99.9% of the viruses, bacteria and germs that exist in almost every home in the world.

4. References

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